DOE/JPL/954995-2

DEVELOP SILICONE ENCAPSULATION SYSTEMS FOR TERRESTRIAL SILICON SOLAR ARRAYS

Second Quarterly Progress Report, July 3—September 29, 1978

October 10, 1978

Work Performed Under Contract No. NAS-7-100-954995

Dow Corning Corporation
Midland, Michigan

U.S. Department of Energy

Solar Energy

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--     7   OF     8
--                    ***DTIC DOES NOT HAVE THIS ITEM***
-- 1 -  AD NUMBER: D429131
-- 5 -  CORPORATE AUTHOR: DOW CORNING CORP  MIDLAND MICH
-- 6 -  UNCLASSIFIED TITLE:     DEVELOP SILICONE ENCAPSULATION SYSTEMS FOR
--      TERRESTRIAL SILICON SOLAR ARRAYS.
-- 9 -  DESCRIPTIVE NOTE: QUARTERLY PROGRESS REPT., NO. 2, 3 JUL - 29 SEP
--      78,
--11 -  REPORT DATE:      OCT 10, 1978
--12 -  PAGINATION:     41P
--15 -  CONTRACT NUMBER:  JPL-954995
--18 -  MONITOR ACRONYM:  DOE/JPL
--19 -  MONITOR SERIES:   954995-2
--20 -  REPORT CLASSIFICATION:  UNCLASSIFIED
--22 -  LIMITATIONS (ALPHA):    APPROVED FOR PUBLIC RELEASE; DISTRIBUTION
--      UNLIMITED. [redacted]
--33 -  LIMITATION CODES:  1 [redacted]

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DOE/JPL/954995-2
Distribution Category UC-63b

SECOND QUARTERLY PROGRESS REPORT

Period Covered: July 3, 1978 - September 29, 1978

DEVELOP SILICONE ENCAPSULATION SYSTEMS FOR TERRESTRIAL SILICON SOLAR ARRAYS

JPL Contract 954995

For

JET PROPULSION LABORATORY
4800 Oak Grove Drive
Pasadena, California 91103

The JPL Low-cost Silicon Solar Array Project is sponsored by the U.S. Department of Energy and forms part of the Solar Photovoltaic Conversion program to initiate a major effort toward the development of low-cost solar arrays. This work was performed for the Jet Propulsion Laboratory California Institute of Technology of agreement between NASA and DoE.

by

DOW CORNING CORPORATION
Midland, Michigan 48640

October 10, 1978

CONTENTS

I. SUMMARY AND REVIEW

This study for Task 3 of the Low Cost Solar Array Project (LSA) funded by DoE is directed toward the development of a cost effective encapsulation system for photovoltaic modules using silicone based materials. It is a cooperative effort between Dow Corning Corporation, the major supplier of silicones and silicone intermediates, and Spectrolab, a leading photovoltaic manufacturer.

The technical approach of the contract effort is divided into four sequential tasks:

1) Technology Review (Reported in the First Quarterly Report)

   A review of:

   a) The performance of clear silicone and modified silicone materials subjected to extended periods of outdoor weathering.

   b) The experience of the photovoltaic industry using silicone encapsulants.

   c) The industrial experience of protecting electronic devices with silicone materials.

   d) The results of weathering silicone based protective coatings.

2. Generation of Concepts for Screening and Processing Silicone Encapsulation Systems.

   a) Selection of the most appropriate current silicone and silicone based coatings for the intended application. (Reported in the First Quarterly Report)

   b) Identification of viable encapsulation systems and potentially cost effective materials of fabrication. (Reported in the First Quartertly Report)

c) Selection of stress tests for the encapsulation concepts.

d) Ranking of the encapsulation concepts based on their performance in the screening tests.

3. Assessment of Encapsulation Concepts

a) Fabrication of mini-modules using state-of-the-art technologies and the best encapsulation concepts from the screening tesk.

b) Tabulation and ranking of the test results based on performance, cost and processability.

4. Evaluation of Encapsulation Concepts

Mini-modules designed to JPL specifications and utilizing the highest ranked concepts from 3. b) will be built, stressed and evaluated.

TECHNICAL PROGRESS IN 2ND QUARTER

1) Weather-Ometer® stressing of silicones with known weathering characteristics was started during the first quarter. The exposure to Sunshine Carbon Arc® filtered UV radiation was continued throughout the 2nd quarter and the samples monitored for change. No significant degradation has occurred to date after as much as 1200 hours of exposure.

2) The effect of dirt pickup and retention during exposure outdoors was initiated during the 2nd quarter. The effect of dirt is being monitored by measuring the change in short circuit current of encapsulated cells.

3) The concept of using dirt resistant silicone resins as UV sensitive pottants was investigated during the 2nd quarter Low levels of some UV absorbing compounds were effective in decreasing the transmission of short wavelength radiation without decreasing the trans-

mission of usable light. The highest level of UV absorber which can be incorporated without significantly affecting the physical properties or its transparency at visible and near infrared wavelength radiation will be determined next quarter.

4) The encapsulation of 2-cell circuits for temperature-humidity cycling and thermal cycling stress was started this quarter. The effect of these stress tests on cell performance and integrity of the encapsulation system will be reported next quarter.

II. INTRODUCTION

The goal of this program is the development of a cost effective encapsulation system for photovoltaic modules based on silicone materials consistent with the LSA cost goals of $0.50/watt by 1985. It is a co-operative effort between Dow Corning Corporation and Spectrolab.

The effort is divided into four sequential tasks:

1) Technology Review
2) Generation of Concepts for Screening and Processing Encapsulation Systems
3) Assessment of Encapsulation Concepts
4) Evaluation of Encapsulation Concepts

The Technology Review was completed and reported in the First Quarterly Report. Several promising encapsulation systems and silicone based materials appropriate for use in these systems have been identified. These were also reported in the First Quarterly Report. The work during this current quarter was primarily directed towards the following four tasks:

1) Weather-Ometer stressing the silicones with known weathering characteristics
2) Effect of soiling and dirt retention on cell performance
3) Silicone covers containing UV screening agents
4) Encapsulation of 2-cell circuits for temperature cycling/humidity cycling

The Sunshine Carbon Arc Weather-Ometer stressing of silicone materials with known weathering characteristics was started during the first quarter and continued throughout the second quarter. The samples were checked periodically for changes in the properties which had been measured and reported on the original outdoor exposure samples.

One cell circuits were coated with silicone based materials which passed the accelerated soiling test reported in the First Quarterly Report. The output of these cells was monitored as a function of outdoor exposure time to determine the effect of dirt accumulation on cell performance.

Several UV screening agents were incorporated into silicone materials which passed the accelerated soiling test. The light transmittance vs wavelength for several UV absorbers at different concentrations was plotted.

Lo-Iron™ sheet glass and Super Dorlux® have been identified as potential candidates for use as superstrate and substrate respectively. These structural supports are being used with thin silicone based coatings over 2-cell circuits in JPL humidity and thermal cycling tests.

III. RESULTS AND DISCUSSION

A. Weather-Ometer Stressing vs Weathering History of Silicone and Modified Silicone Materials

The weathering history of twelve silicone based materials was reported in the First Quarterly Report. In Table I is a summary of those materials, the properties monitored and the duration and site of outdoor exposure. Samples of these materials, or samples of products which most closely duplicate the ones reported that are no longer available, have been placed in our Atlas Sunshine Carbon Arc Weather-Ometer. The same properties that were monitored during outdoor weathering are being tracked during artificial weathering. The mode of degradation as a function of time will be monitored and correlations with natural weathering will be made when appropriate.

A comparison of property changes in the materials listed for the two methods of weathering is presented in Table II. There has been no significant change in any of the Weather-Ometer stressed materials. Therefore, at this time none of the silicone or modified silicone resins or elastomers have been exposed to as much weathering stress as that reported in the Historical Weathering of Silicones section of the Technology Review of the First Quarterly Report. This evaluation is still in progress and will be updated in the next quarterly report.

B. Candidate Silicone Materials

The candidate silicone materials that were reported in the First Quarterly Report are reviewed in Table III. The silicone and modified silicone resins were chosen on the basis of similarity to materials with known weatherability, cost, initial tangential modulus, accelerated dirt pickup test results and the ratio of the content of organic phenyl substitution to methyl substitution on the backbone of the silicone resin. Of the nine materials listed in the First Quarterly Report, the five remaining are the lowest cost and constitute a spectrum of modulus and Ø/Me ratio. Dow Corning® X1-2577 conformal coat and RTV 3140 have a low rating in accelerated dirt pickup but low surface tack. Therefore, they have remained as viable candidates. The acceptability on the basis of dirt pickup is being verified in an outdoor exposure test.

One adhesive that was added to the list is RTV 3140. Some bubbling on the backside of cells was experienced with Dow Corning 96-083 adhesive. Although 96-083 adhesive has desireable performance charcteristics, it was replaced with the RTV which does not bubble.

During the second quarter the initial tangential modulus of the silicones and modified silicone resins was re-run. The values that were obtained and reported in the First Quarterly Report were very dependent on how the line tangent to the start of the curve was drawn. For the values reported here, the Instron cross arm speed was run at the slowest rate possible and the chart paper was run at the highest rate possible. The initial portion of the curves obtained was relatively flat. This made the modulus values more accurate and reproducible.

One piece of information reported in this First Quarterly Report that was incorrect was the Ø/Me ratio of Dow Corning® 808 resin. It has a low Ø/Me ratio. To rank the remaining candidates relative to each other with respect to this parameter, the description reported here in Table III for each resin should be used.

C. Outdoor Dirt Pickup

The outdoor soiling of candidate encapsulation materials was evaluated in the following manner: one cell circuits were glued to the top surface of 3" x 9" x 1/8" soda lime glass, and coated with the candidate silicone materials. The coatings ranged from 5 to 10 mils in thickness. These samples were exposed on the roof of the Dow Corning development building at its industrial site in Midland, Michigan (see Figure 1). A summary of the materials used to prepare each sample appears in Table IV. The short circuit current (Isc), open circuit voltage (Voc) and current at .375 volts (to approximate maximum power, Pmax) was measured before encapsulation, immediately after encapsulation and periodically after outdoor exposure. Figure 2 is an IV curve for one of the cells used. The current at .375v was chosen because of its proximity to the knee of the curve. The results of our measurements are in Table V. The equipment used to measure the output of the cells consisted of a chamber containing:

1. A projector with an ELH, tungsten dichroic lamp (see Figure 3)
2. A SIM-PLY-TRO® pyrometer to monitor temperature
3. Hewlett Packard 3465A Digital Multimeter

The illumination in the chamber is adjusted to 1000 w/m^2 by a standard reference cell from NASA Lewis Research Center. The light source is adjusted to give a short circuit current of approximately 140ma and an open circuit voltage of approximately 478mv at 28°C. Originally,

a digital voltmeter that was part of the illumination chamber apparatus was used to measure the output of the cells. It had been used on the unencapsulated cells, the newly encapsulated cells and after the first two exposure periods. However, this meter could not be correctly calibrated so we switched to the Hewlett Packard instrument. With this meter we obtained an IV curve for the reference cell very similar to the one provided by NASA Lewis Research Center. The Isc and Voc were essentially identical at 28°C allowing us to adjust the illumination of 1000 w/m^2 for measuring the experimental cells. A graph of the IV curve for this reference cell is shown in Figure 4. Figure 5 shows the IV curve supplied with the reference cell by NASA Lewis, and they are in good agreement. The Voc readings of the first meter could be adjusted to the correct values obtained with the Hewlett Packard instrument by multiplying by a factor of 1.15. This correction factor was used to adjust Voc values which were made with the first meter.

As seen by the short circuit current values in Table IV, there has been some drop in the output of the encapsulated cells exposed outdoors. Table VI summaries the results of the effect of outdoor dirt pickup in an industrial environment on the candidate silicone and silicone based resins and elastomers. The Sylgard® 184 and Dow Corning 3140 elastomers and Dow Corning X1-2577 conformal coating are visibly picking up some dirt. These samples are not washed. However, duplicate samples of these outdoor soiling specimens will be prepared and used to evaluate cleanability. The X1-2561

resin has lifted from the glass substrate. Primer systems to improve the adhesion of X1-2561 resin to glass will be evaluted. Dow Corning® 808 resin and Dow Corning® 840/B48N acrylic resin blend still look very good. Both remain essentially unchanged in output or physical appearance after 44 days exposure.

D. Use of UV Screening Agents in Protective Top Covers

One potential design for a cost effective photovoltaic array is to use an inherently weatherable protective top cover over a low cost non-weatherable UV sensitive pottant, such as ethylene vinyl acetate. The top cover would need to be heavily loaded with UV screening agent to protect the UV sensitive pottant. Because of this, samples of nine common UV screening agents (UV absorbers) were selected to be blended into the three candidate silicone based resins that had acceptable ratings in the accelerated dirt pickup test (reported in First Quarterly Report). These resins were Dow Corning 808 resin, B48N acrylic/Dow Corning 840 resin blend and Dow Corning X1-2561 resin. The nine UV screening agents considered for use in this study are listed in Table VII along with reasons for eliminating those that were considered but not used.

By mixing 250ppm each of 1,4 Dihydroxynaphthalene (1, 4-DHN) 1,4-naphthoquinone (1,4 NQ) and 2,4-Dihydroxybenzophenone (2,4-DHBP) into Dow Corning 840/B48N acrylic resin blend the results in Table VIII were attained. The radiation below 400nm was screened out by all of the UV screens but usable light above 400nm was increased slightly with 1,4 DHN and 2,4-DHBP. Figures 6 thru 11 give the transmission curves of 250 and 1000 ppm of the three screening agents in the resin blend. Transmission has been normalized to

a film thickness of one mil. The trend of decreasing UV transmission and increasing visible transmission did not appear in the 1000 ppm samples.

The only other resin that has been cured containing UV screening agents is Dow Corning X1-2561 resin. However, as seen from the transmission results in Figures 12 thru 15, there were no significant changes in transmission. It was found that the UV screening agents were not very soluble in the resin. For this reason, a solvent mixture of toluene and isopropanol compatible with the resin and UV screens was found. Cured films containing the UV screen added by means of the solvent mixture will be studied and reported in the next quarterly. It does appear from the graphs obtained that 1,4 NQ, 1,4 DHN, 2,4-DHBP and 2-hydroxy-1, 4-Napthoquinone (2-H-1, 4-NQ) may also have the effect of augmenting the usable light transferred to a solar cell while cutting out the harmful UV radiation.

Dow Corning 808 resin which passed the accelerated dirt pickup test remains to be evaluated as a cover material for use with UV screening agents. This will be completed next quarter. The maximum level of UV screening agent which can be incorporated in the silicone based materials without adversely affecting visible light transmission or physical properties of the material will be determined. Effects on the cure of the resin are being monitored by initial tangential modulus. There are no data to report at this time. These data will be reported in the next quarterly. In the work thus far, there have been no significant effects of the UV screens on the cured film properties of the resins.

To date, the use of silicone top cover containing UV screening agent is still a workable concept.

VI. PLANS FOR THE FOURTH QUARTER OF 1978

1. The screening effects of UV absorbing agents in silicone based top covers will be completed next quarter. Ultraviolet degradation of top covers containing of UV screening agents and their ability to protect UV sensitive polymers will be determined.

2. The outdoor dirt pickup test will be continued during next quarter. We will continue to monitor change in Isc as a function of time and will begin a study designed to assess the cleanability of these encapsulation materials. This study will use replicates of these same samples monitored by measuring the output of one-cell circuits.

3. Weather-Ometer stressing of known weatherable samples will continue as well as tracking their change in properties.

4. Encapsulation of 2-cell circuits with our best encapsulation systems has just begun. Temperature cycling of the encapsulated circuits will be run in November. The effects of humidity and temperature cycling will also be determined in November. A failure analysis will be ongoing during this time and the appropriate changes in the encapsulation systems will be made. A complete failure analysis review and encapsulation system selection will be made in January, 1979.

5. Mini-modules, meeting the required JPL specifications, will be designed but not built in the fourth quarter. Display modules will be prepared for the 11th PIM meeting in December.

This document, pages 1-37, including Tables I-VIII and Figures 1-15 constitute this report submitted by William E. Dennis and Mary D. Fey.

TABLE I: SUMMARY OF WEATHERING HISTORY OF SILICONE BASED MATERIALS

RESIN	PROPERTIES	SITE OF DURATION OF EXPOSURE
1. DC®808 resin	gloss, checking, dirt retention, appearance	6 years Florida
2. DC®901 resin	transmission on open weave cloth	4 years Arizona and 4M Langleys at DSET
3. B66 acrylic/ DC 840 resin	checking, gloss, appearance	13 years Texas and 7 years Florida
4. DC®996 resin	gloss, color change, checking	10 years Midland
5. DC®802 resin	gloss, color changes, checking	10 years Midland
6. LS-53 rubber	checking, appearance	20 years Florida
7. RTV 132 elastomer	tensile strength, elongation, appearance	20 years Florida
8. RTV 501 elastomer	durometer, tensile, elongation, appearance	16 years Florida
9. 55U Silastic rubber	durometer, tensile, elongation	19 years Florida
10. Silastic® 675 rubber	durometer, tensile, elongation	19 years Florida
11. RTV 3140 elastomer	durometer, tensile, elongation, appearance	
12. RTV 781 building sealant	durometer, dirt pickup	20 years Wisconsin

TABLE II: OUTDOOR vs ATLAS SUNSHINE CARBON ARC WEATHEROMETER STRESSING: EFFECT ON PROPERTIES

Resin or Elastomer	Site and Duration of Exposure	Condition of Sample
1. Dow Corning® 808 Resin	6 years Florida 45° south	36% loss gloss (60°) No checking or dirt retention
	1275 hrs. filtered WOM	100% gloss (60°) no checking, no dirt retention
2. Dow Corning® 901 Resin	4 yrs. Arizona - 45° South	99% or original 350-2400 NM transmission
	$4\overline{M}$ Langleys - Emmaqua	94% of original 350-2400 NM transmission
	290 hours filtered WOM	slight increase in 200-2600 NM transmission
3. B66 Acrylic/DC® 840 Resin	13 years Texas	Slight dirt retention, no loss gloss, no checking
	7 years Florida - 45° South	Corrosion protection - 9
	1275 hours WOM	No loss gloss, very slight micro checking, no dirt retention
4. Dow Corning® 996 Resin	10 years in Midland	No loss of gloss, no color change checking rating of 6
	903 hours WOM	No loss of gloss, no checking, no dirt retention
5. Dow Corning® 802 Resin	10 years Midland	No loss gloss, no color change, checking -6
	No longer available	
6. LS 53 Rubber	20 years Florida	Slight dirt and mildew, no cracking or checking
	1275 hours WOM	No change

TABLE II: (cont.) OUTDOOR vs ATLAS SUNSHINE CARBON ARC WEATHEROMETER STRESSING: EFFECT ON PROPERTIES

Resin or Elastomer	Site and Duration of Exposure	Condition of Sample
7. RTV 132U Elastomer	20 years Florida	Some loss tensile and elongation same as LS53
	1275 hours WOM	Slight trace of dirt
8. RTV 501 Elastomer	16 years Florida	Slight increase in durometer, decrease in tensile and elongation, some checking
	1209 hours WOM	No checking
9. 55U Silastic Rubber	19 years Florida	Slight dirt retention and mildew
	1275 hours WOM	No change
10. Silastic 675 Rubber	19 years Florida	Slight decrease in durometer, tensile and elongation, some surface cracking
	1275 hours WOM	No change
11. RTV 781	20 years Wisconsin	Dirt pickup
		Slight lowering durometer hardness
Building sealant	903 hours WOM	No loss of 20° gloss, some blisters

TABLE III: CANDIDATE SILICONE ENCAPSULATION MATERIALS

SILICONE OR MODIFIED SILICONE	USE	$/LB SOLIDS	$/FT²/MIL	INITIAL TANGENTIAL MODULUS (psi)	ACCELERATED DIRT PICK-UP	Ø/Me RATIO
A. DC® 840/B48N resin blend	1. conformal coating 2. UV containing top cover 3. pigmented bottom cover	4.32/1.51	.012	43,5000	9.5-10	high
B. X1-2561 resin	same as A	10.00	.06	--	9	medium
C. DC® 808 resin	same as A	5.08	.026	27,500	5	low
D. X1-2577 conformal coating	same as A	9.33	.052	2,450	2	low
E. RTV 3140	same as A	11.19	.06	--	0-1	negligible
PRIMERS						
A. Z-6082 silane		4.30	.005/5μ	--	--	--
B. Z-6030 silane		8.65	.01/5μ	--	--	--
C. Z-6020 silane		6.35	.0075/5μ	--	--	--
D. DC® 1204 primer		5.40	.004/5μ	--	--	--
E. DC®3-6060 primer		NA	--	--	--	--
ADHESIVES						
A. 96-083 adhesive		8.66	.05	--	--	--
B. RTV 3140		See E	See E	--	--	--

TABLE IV: One-Cell Modules for Outdoor Dirt Pick-up

(1/8" Soda Lime Glass Substrate)

GLUE (THICKNESS)	TOP COVER (THICKNESS)	COMMENTS
DC® 96-083 Adhesive (5 mils)	DC® 184* (5 mils)	Cured 30 min. 180°C, Sylgard® Primer on glass and cell, draw down
DC® 96-083 adhesive (5 mils)	X1-2577 resin (5 mils)	1204 primer on glass and cell air dried 3 days draw down
DC® 96-983 adhesive (5 mils)	DC® 840/B48N resin (5 mils)	no primer air dry 3 days draw down
RTV 3140 (5 mils)	RTV 3140 (5 mils)	Sylgard primer cured 3 days air dry draw down
X1-2561 resin (5 mils)	X1-2561 resin (10 mils)	DC® 3-6060 primer flow coated 30 min. at 90°C cure
DC® 808 resin (5 mils)	DC® 808 resin (3 mils)	2% PA21 catalyst (amine) thin draw down on panel cell dipped in DC® 808 and set on wet panel. 30 min. cure at 105°C cell primed with PA21.

* State-of-the-art encapsulant

TABLE V

Output of Encapsulated Cells Exposed Outdoors for Dirt Pick-up

TOPCOVER		Before Encapsulation	After Encapsulation	1st Exposure Period		2nd Exposure Period		3rd Exposure Period		4th Exposure Period	
RTV 184	Isc	485ma	489ma	503ma	days	448ma	26 days	464ma	37 days	465ma	44 days
	Voc	572mv	577mv	569mv		576mv		584mv		581mv	
	I_{375}	—	—	—		—		326ma		317ma	
X1-2577 Conformal Coating	Isc	481	469	499	11 days	441	11 days	450	37 days	452	44 days
	Voc	581	583	570		580		589		588	
	I_{375}	—	—	—		—		321		311	
RTV 3140	Isc	495	487	499	11 days	430	26 days	457	37 days	452	44 days
	Voc	570	573	559		569		598		578	
	I_{375}	—	—	—		—		324		312	
X1-2561 Resin	Isc	467	458	478	11 days	412	26 days	396	37 days	396	44 days
	Voc	567	549	559		567		570		571	
	I_{375}	—	—	—		—		279		273	
DC-840/B48N Resin	Isc	464	505	469	7 days	398	22 days	461	33 days	463	40 days
	Voc	565	574	555		566		573		570	
	I_{375}	—	—	—		—		320		272	
DC-808 Resin	Isc	409	505	453	7 days	426	22 days	383	33 days	416	40 days
	Voc	567	577	561		567		570		579	
	I_{375}	—	—	—		—		288		297	
NASA Reference Cell (No Weathering)	Isc	147	147	138		133		133		141	
	Voc	591	591	587		589		590		591	
	I_{375}	—	—	—		—		122		132	

TABLE VI

% Loss in Isc and Description of Samples in Outdoor Dirt Pick-up Test

	% Loss in Isc	Description
RTV 184 Elastomer	4%	Visibly picking up dirt
X1-2577 Conformal Coating	6%	OK - picking up some dirt
RTV 3140 Elastomer	8.5%	Visibly picking up dirt
X1-2561 Resin	15%	Delaminated from substrate and 10% loss of adhesion on cell surface at edges.
DC-840/B48N Acrylic Resin	0	slight peeling and blistering of the surface
DC-808 Resin	Slight increase	OK

TABLE VII

UV Screening Agents Considered for Use in Protective Top Covers

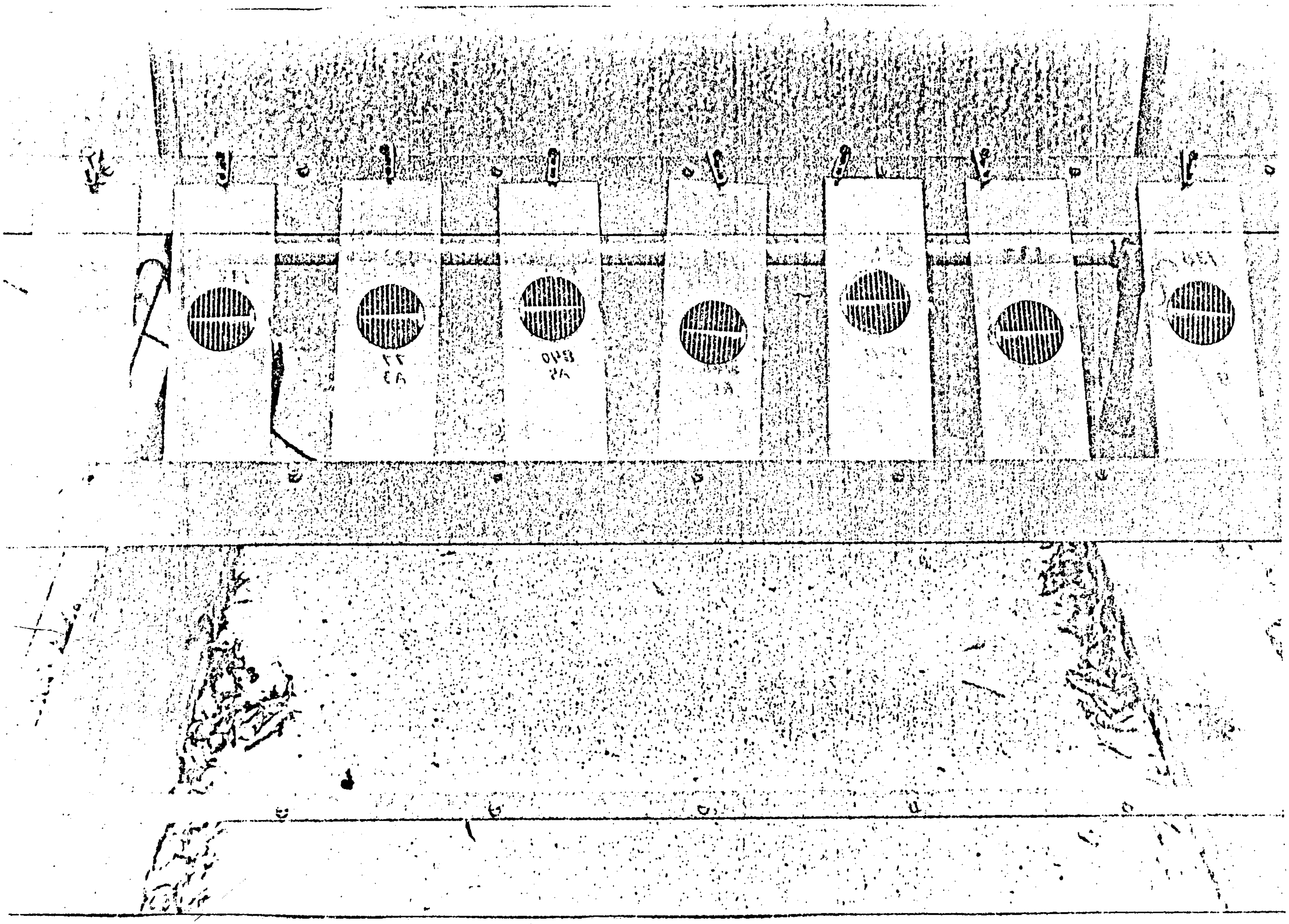
Screening Agent	For Use In	Reason Not Used
1) 1,4 - Napthoquinone (1,4N)	1-2561 resin	DC-808 resin - turns brown DC840/B48N blend - bubbles
2) p-methoxyphenol (P-M)	DC-808 resin	X1-2561 resin - not much effect DC-840/B48N blend - not much effect
3) Catechol (C)	none	Causes burns on contact. Very similar to p-B and R turns DC-808 resin blue with catalyst PA 21
4) p-Benzoquinone (p-B)	none	Very similar to R. Bubbles in X1-2561 resin, turns DC-808 resin dark brown.
5) 1,4 - dihydroxynaphthalene (1,4 -DHN)	X1-2561 resin DC-840/B48N blend	DC-808 resin - turns brown
6) 2-hydroxy-1,4-napthoquinone (2H-1,4-NQ)	X1-2561 resin	DC-808 resin - turns dark DC 840/B48N blend - not much effect
7) Resorcinol (R)	DC-808 resin	X1-2561 resin - not much effect D840/B48N blend - not much effect
8) Hydroquinone (H)	none	Toxicity on contact with skin turns DC-808 resin brown
9) 2,4-dihydroxybenzophenone (2,4-DHBP)	X1-2561 resin DC-808 resin DC-840/B48N blend	

TABLE VIII

Transmission as Percent of Control of Silicones Containing UV Screening Agents
(for DC-840/B48N Acrylic Resin Blend Normalized to 1mil thickness)

		200-400nm	200-1800nm
1,4-DHN	250ppm	96%	104%
	1000ppm	77%	77%
1,4-NQ	250ppm	82%	93.3%
	1000ppm	78%	78.4%
2,4-DHBP	250ppm	89.5%	104%
	1000ppm	72%	89.7%

FIGURE 1



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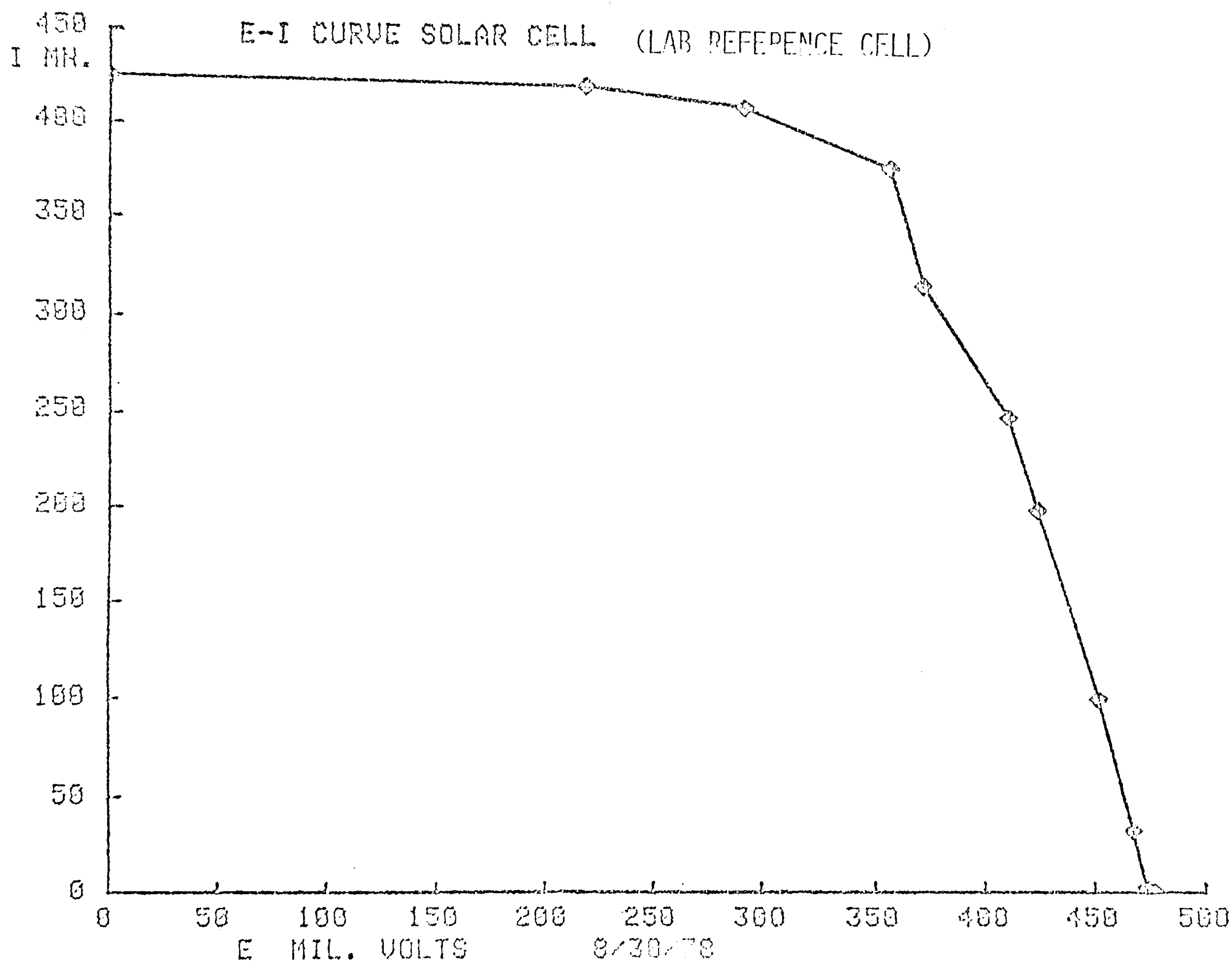
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FIGURE 3

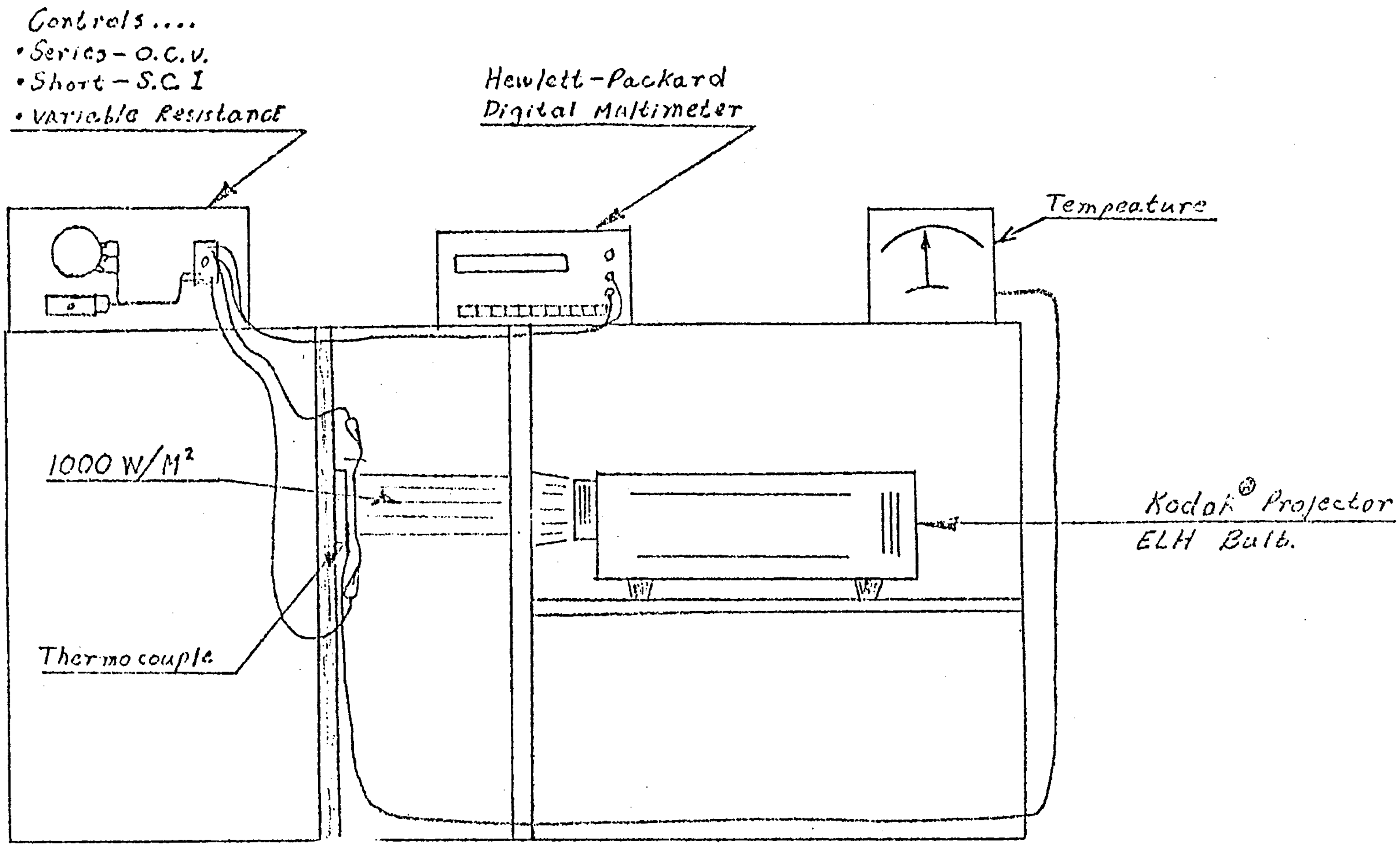

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FIGURE 4

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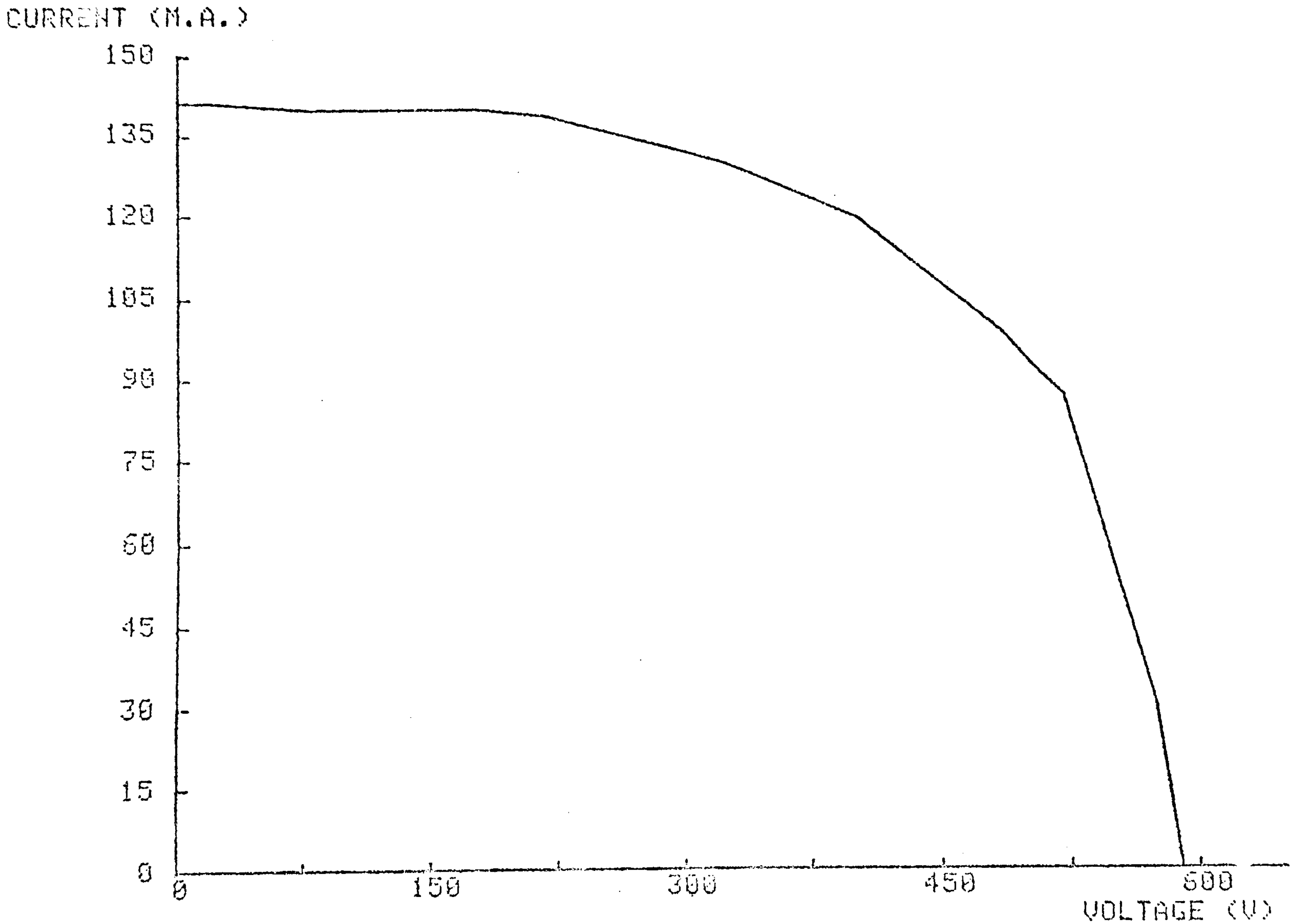

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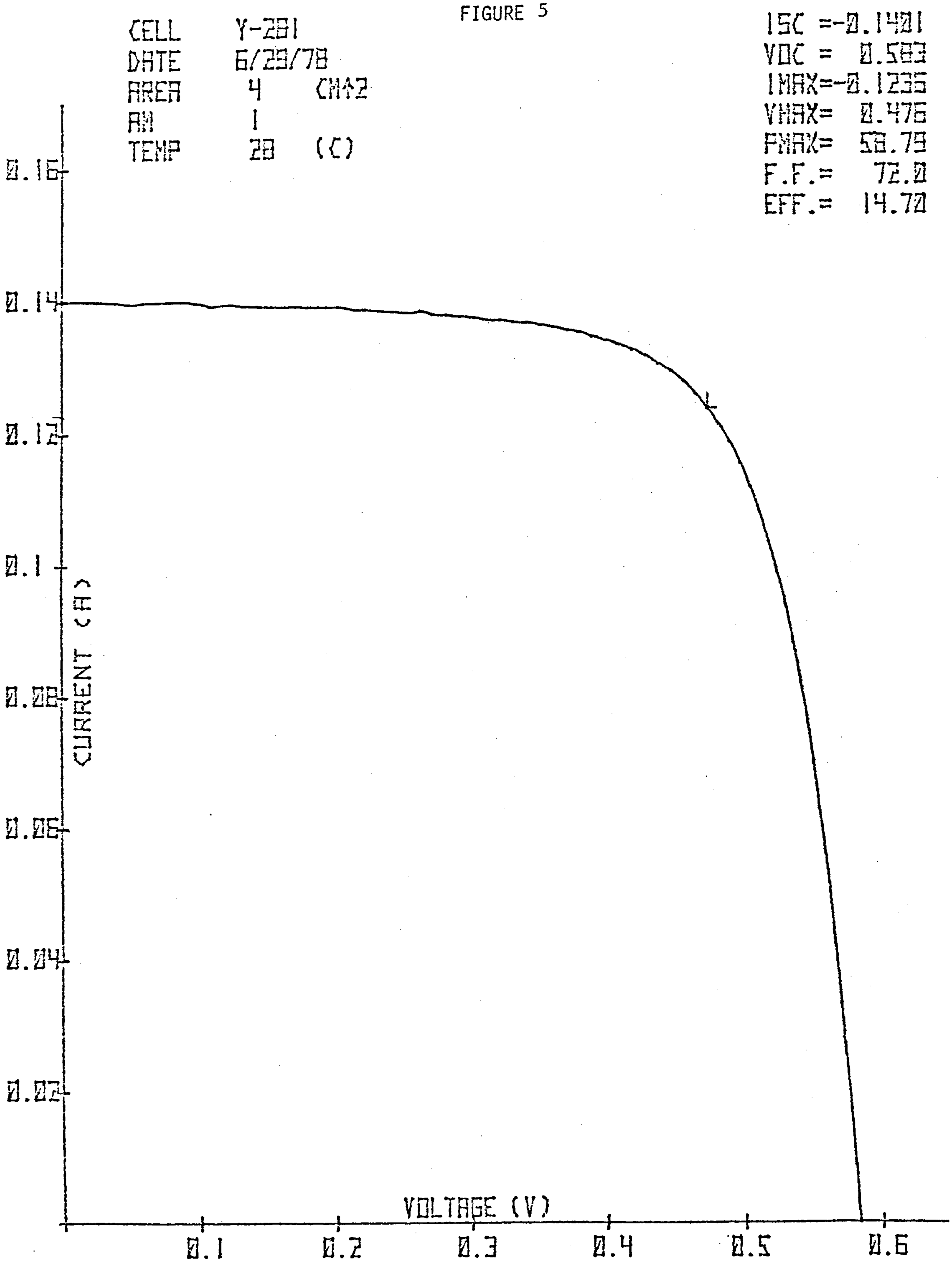

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0.1
0.08
0.06
0.04
0.02
CURRENT (A)
VOLTAGE (V)
0.1
0.2
0.3
0.4
0.5
0.6

FIGURE 6

DC 840/B48N 25/75 BLEND

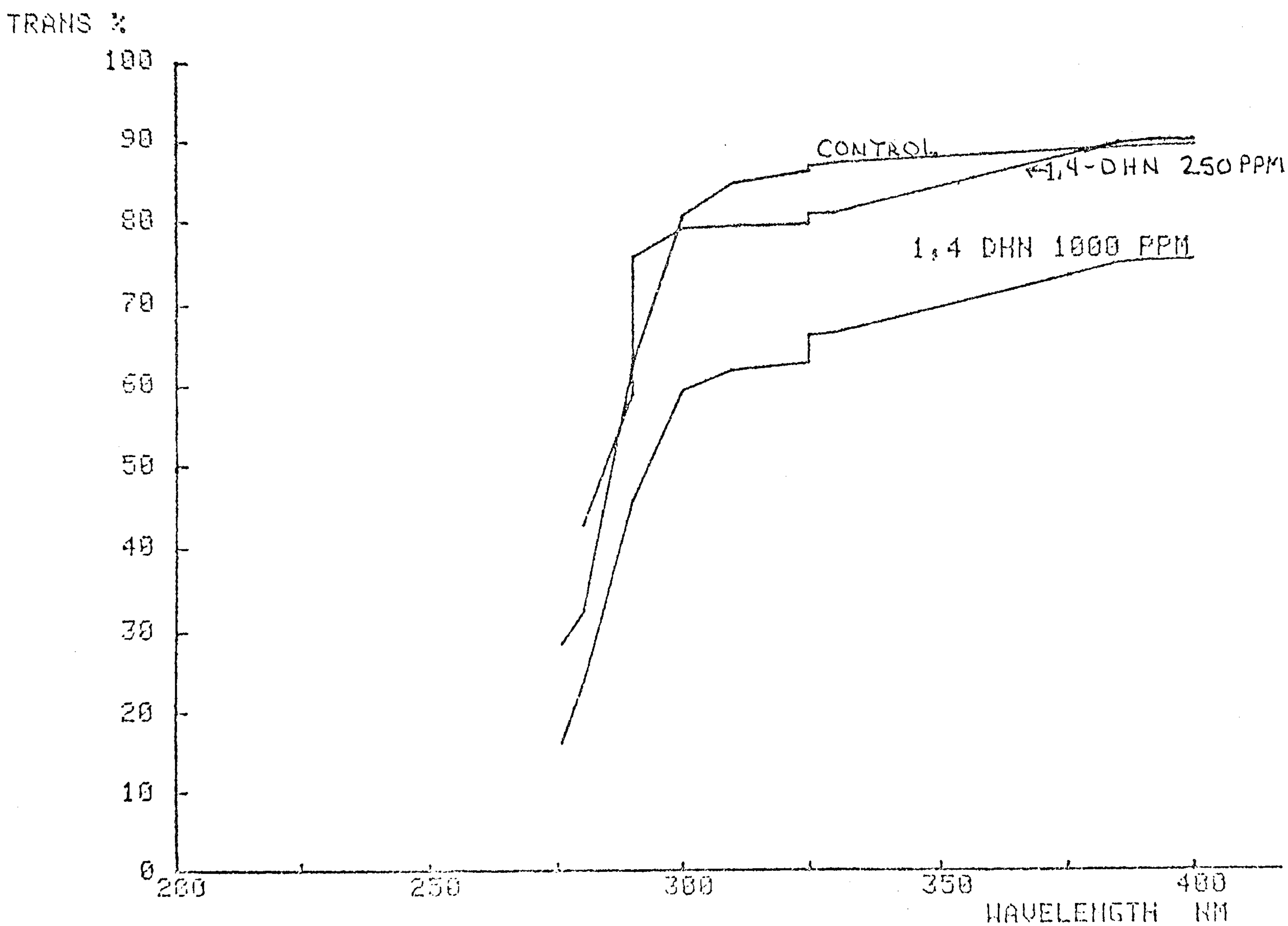


FIGURE 7

DC 840/B48N 25/75 BLEND

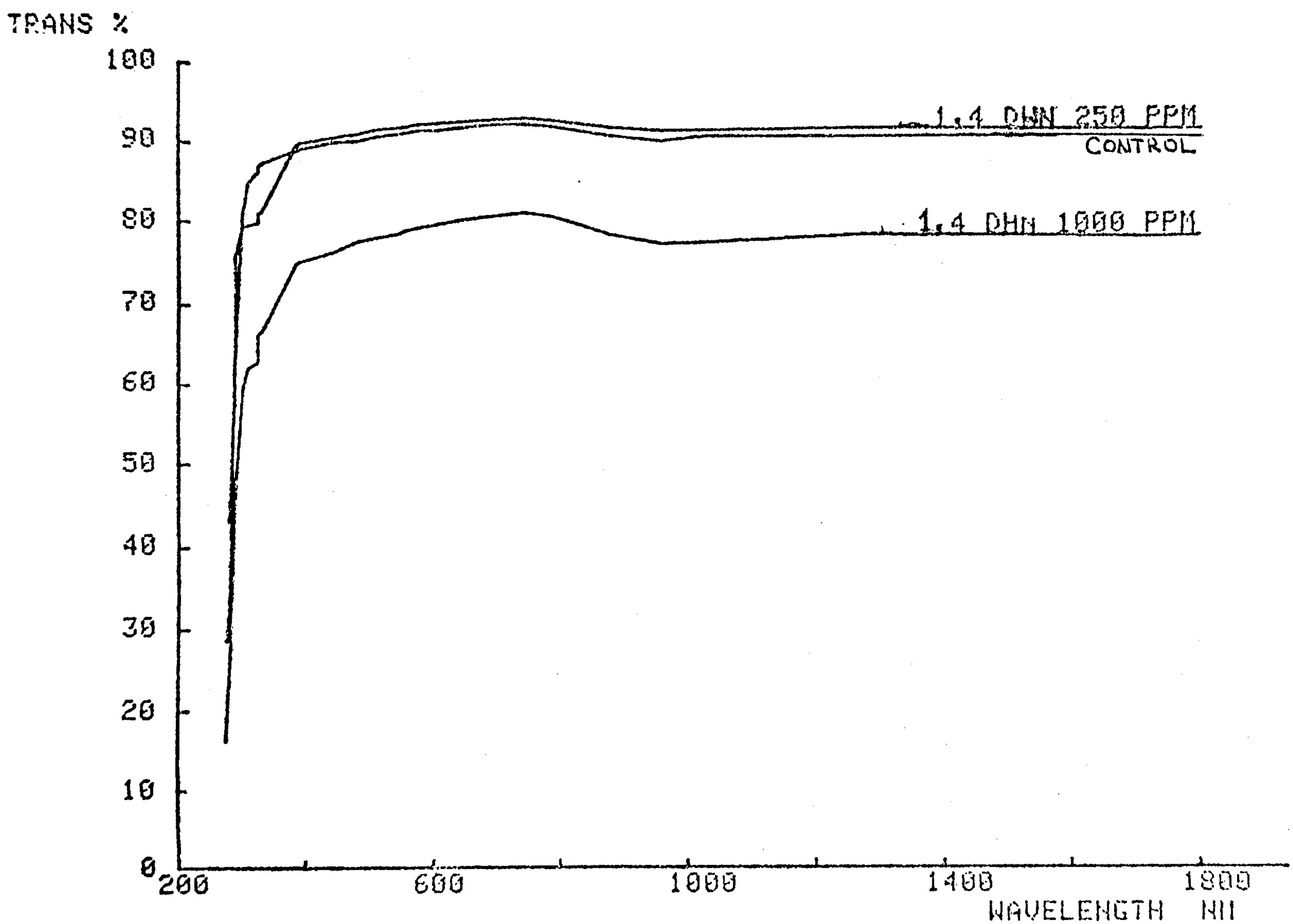


FIGURE 8

DC 840/B40H 25/75 BLEND

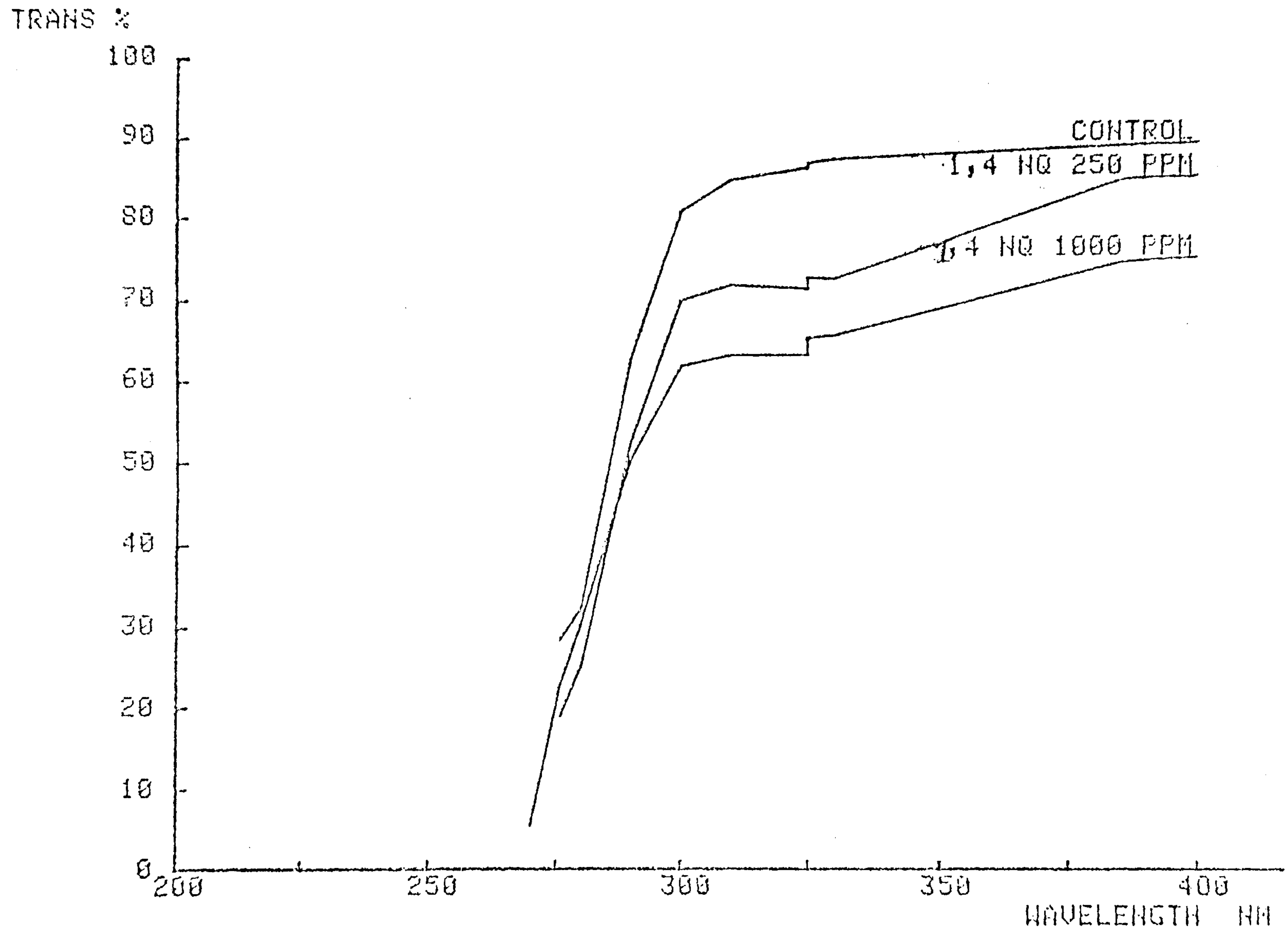


FIGURE 9

DC 840/B48N 25/75 BLEND

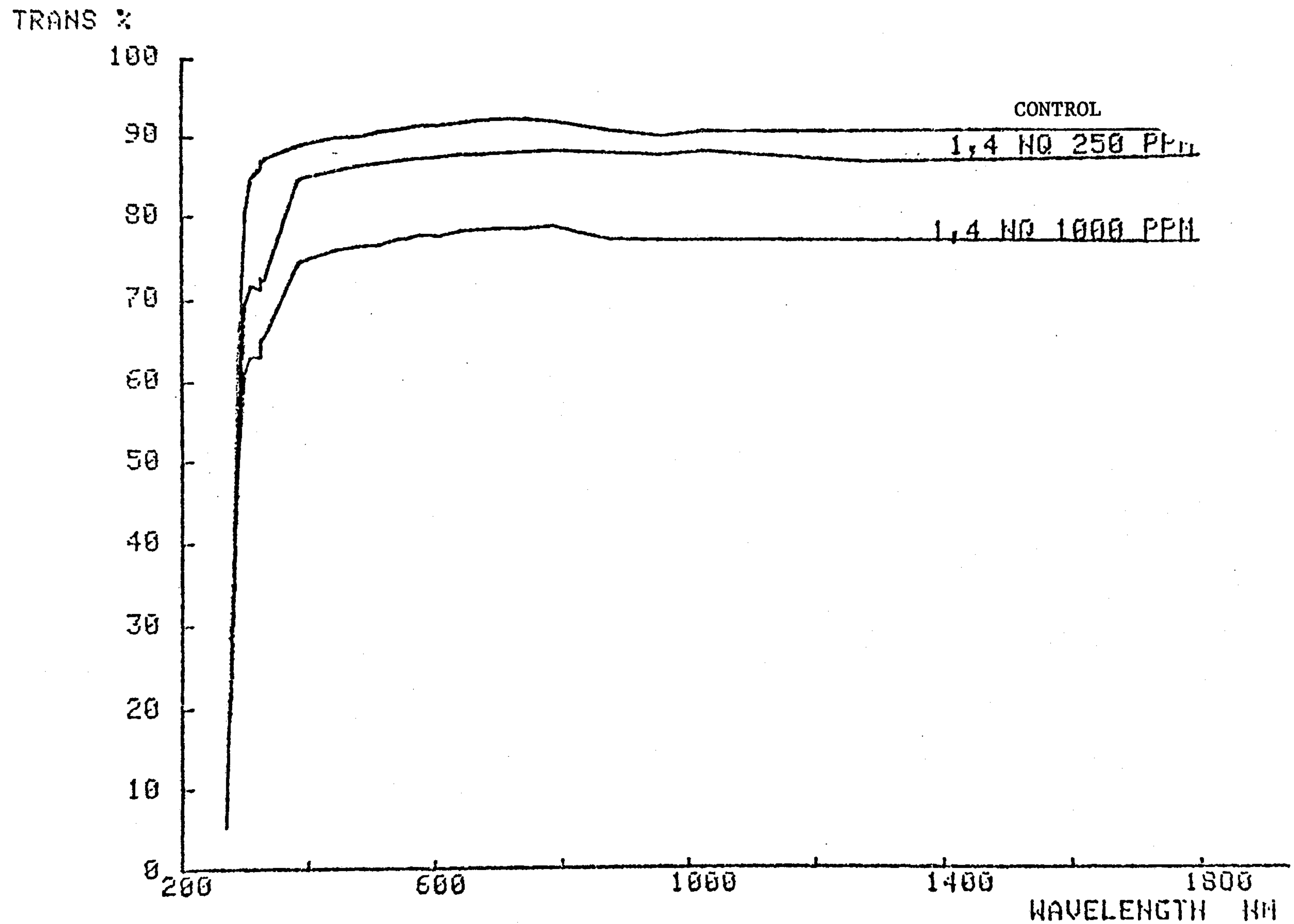


FIGURE 10

DC 840/B48N 25/75 BLEND

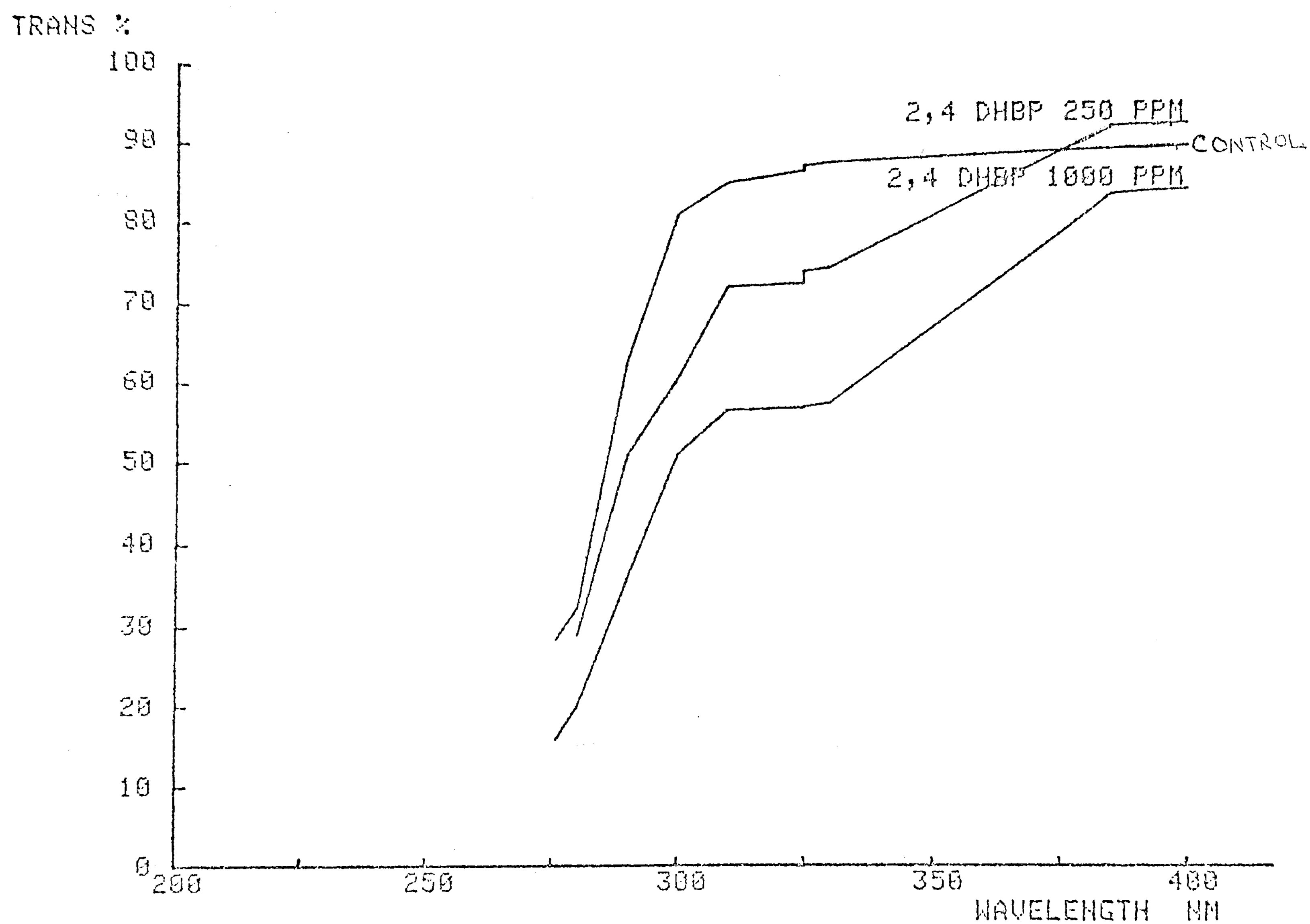
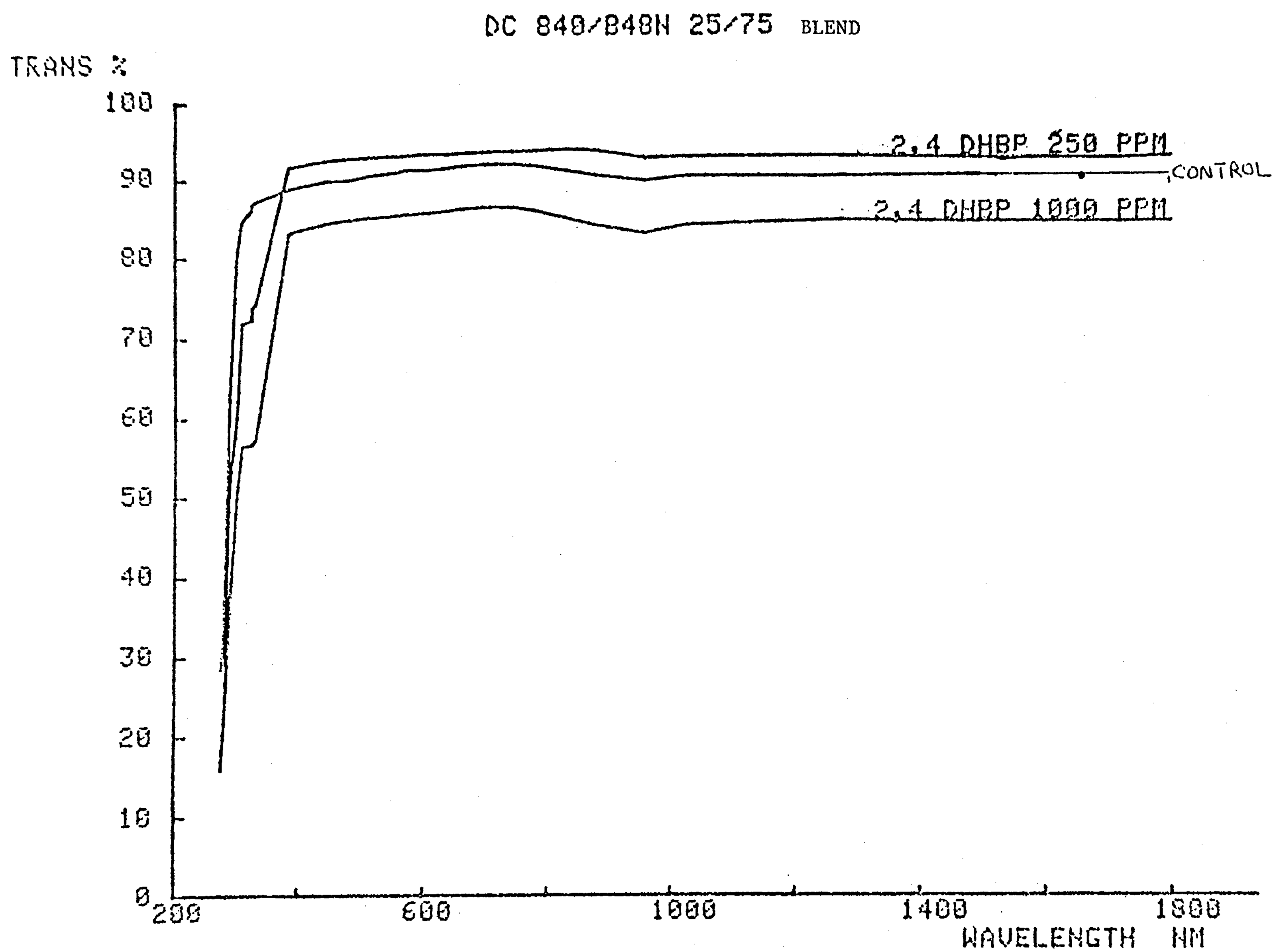


FIGURE 11



DC 840/848N 25/75 BLEND
TRANS %
100
90
80
70
60
50
40
30
20
10
0
200
600
1000
1400
1800
WAVELENGTH NM
2,4 DHBP 250 PPM
CONTROL
2,4 DHBP 1000 PPM

FIGURE 12

XI-1561 resin

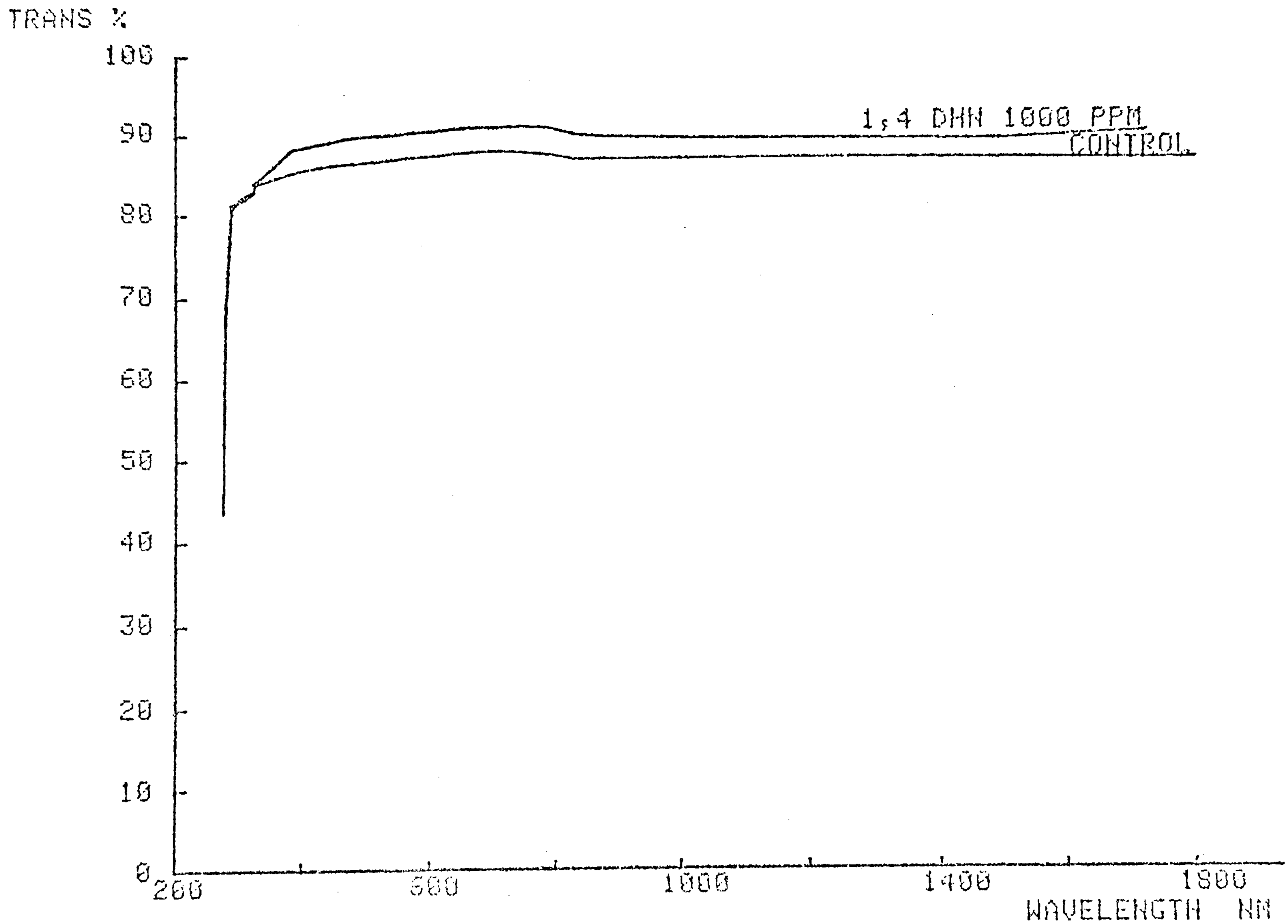


FIGURE 13

XI-1561 resin

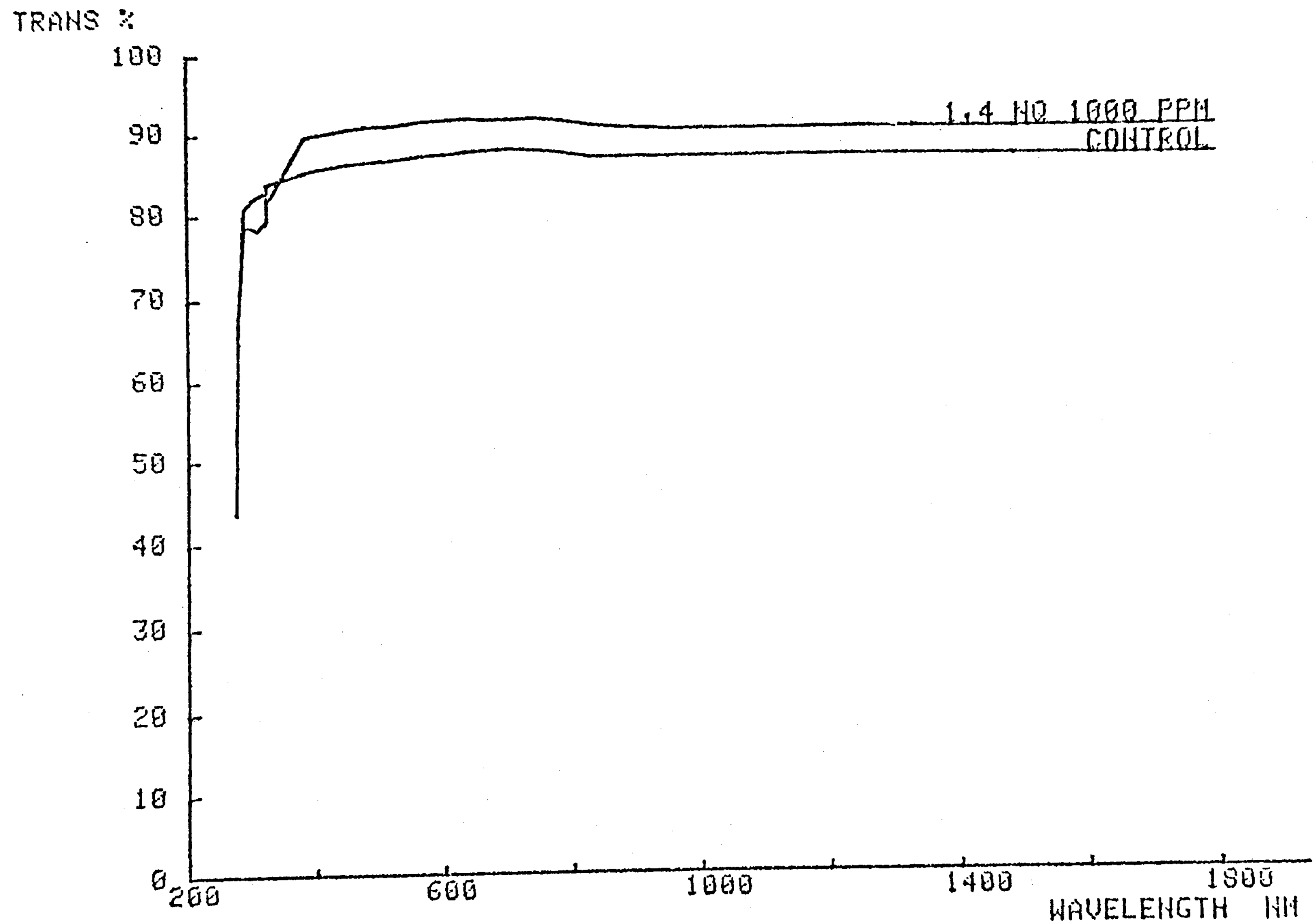


FIGURE 14

XI-1561 resin

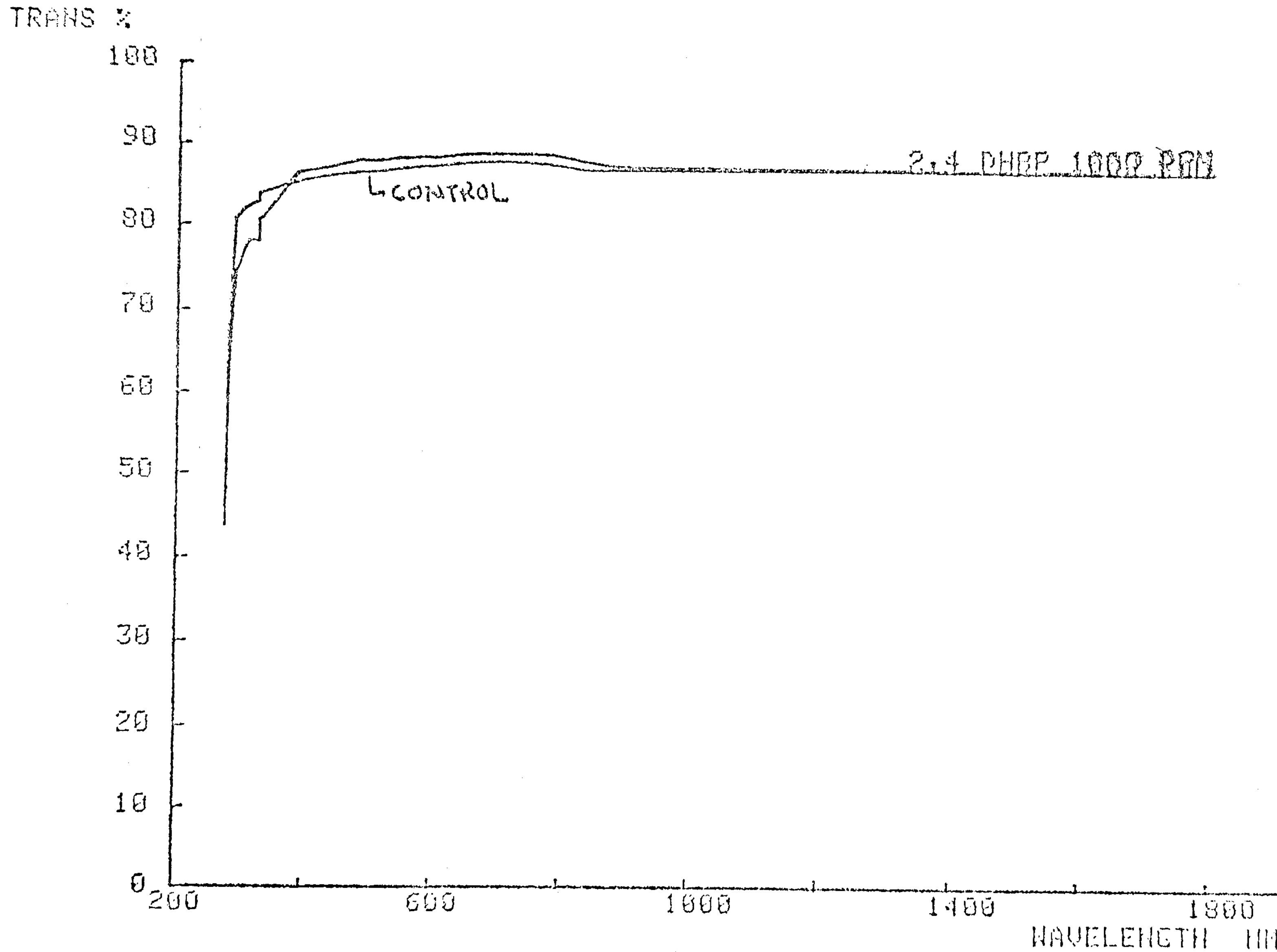
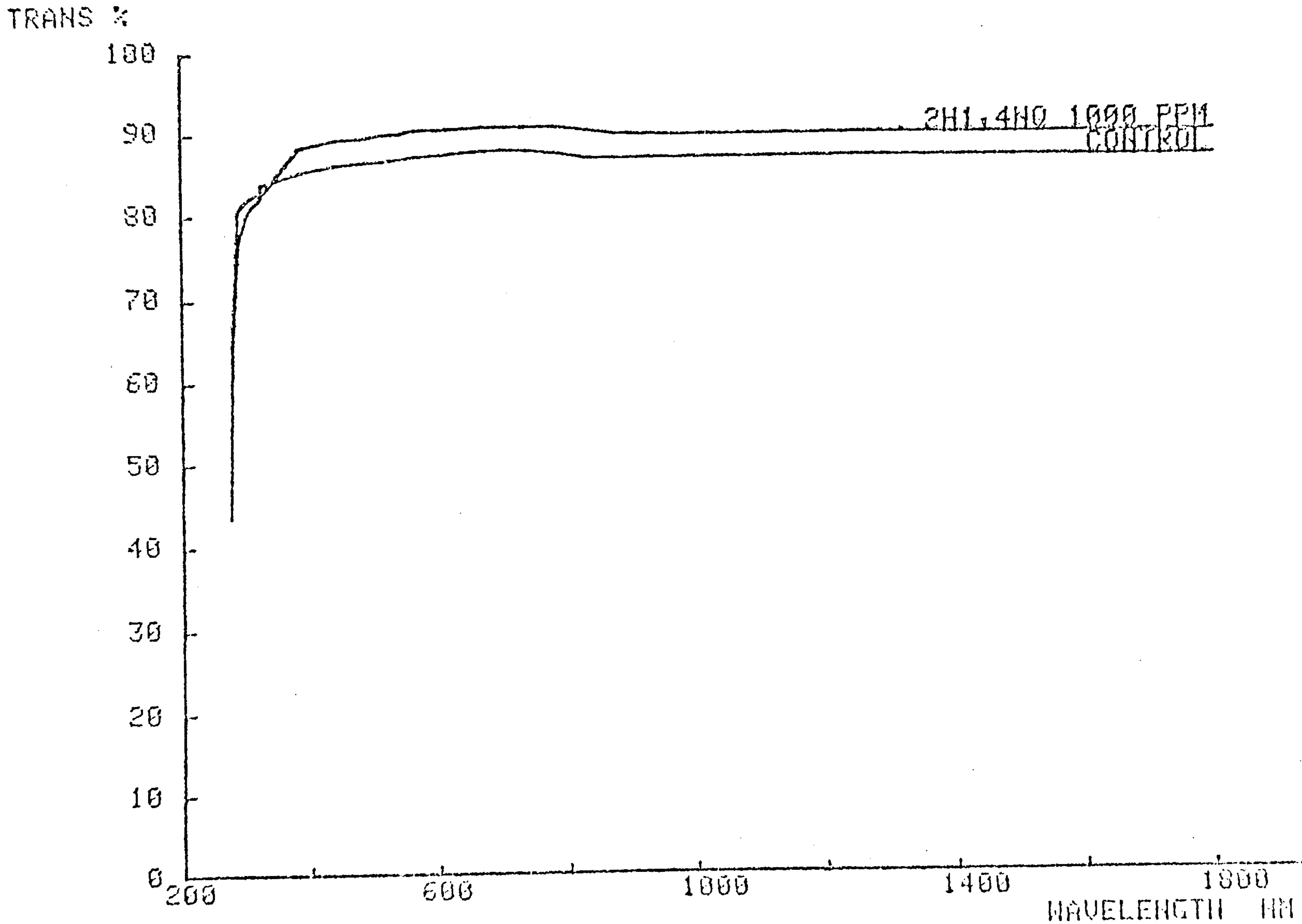


FIGURE 15

XI-1561 resin



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